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DARPA is hoping autonomous robot helicopters will help the US Army win the complex urban battlefields of tomorrow. TIM ROBINSON sizes up the contenders for the Unmanned Combat Armed Rotorcraft (UCAR).

There have been some hard lessons coming out of the Middle East for certain militaries, and none has had more to absorb in recent times than the US Army. One of the highest-profile procurement casualties was its 'crown jewel' RAH-66 Comanche attack/scout helicopter which would have given the US Army a digitised stealthy recon/attack helicopter.

The cancellation of Comanche, which suffered from 'mission creep' and a budget that threatened to swallow the rest of the Army's new toys, has freed up cash for items like defensive missile protection, armour plating and increased maintenance requirements that are needed in Iraq as well as new, simpler, helicopters. However, these fixes, do not address the overwhelming problem as seen in Iraq — the intense vulnerability of the helicopter in modern combat — a fact that has led some commentators to announce that the day of the attack helicopter has gone the way of the mounted knight or dreadnought. The problem is not so much the helicopter itself, for it has always been fragile, but the conditions it fights in.

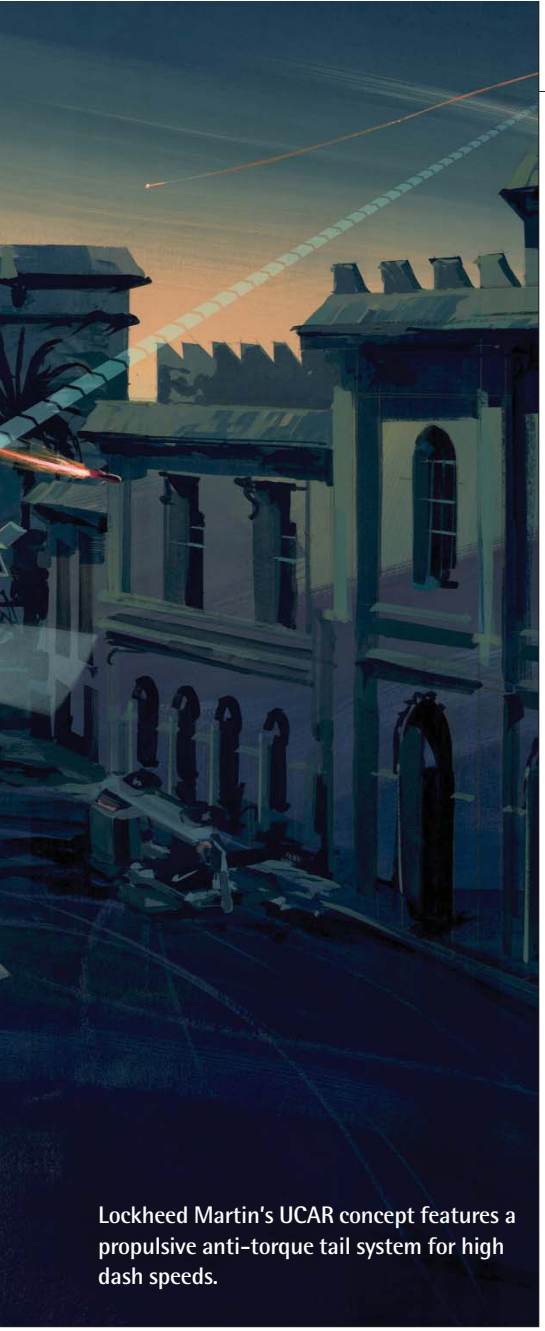
In the hypothetical 1980s Fulda Gap scenario, Western anti-tank helicopters would operate in the countryside, picking off Soviet armour at their missiles' maximum range, before backing off to new defensive positions. This was the case in the 1991 Gulf War where Apaches spearheaded the way on the first day. However in 1993, in Somalia, the vulnerability of helicopters over hostile urban battlefields was highlighted dramatically.

This has been re-emphasised by operations in Iraq and Afghanistan since 2001. In particular a mixed raid of the US Army's hi-tech AH-64D Longbow Apaches and AH-64A models in 2003 led to a severe drubbing by Iraqi forces, who had set up hidden AA positions to ambush the choppers. One helicopter was downed and all returned home with varying levels of damage from essentially low-tech weapons like light AAA and rocket-propelled grenades.

US Army Aviation crews are now reported to be flying defensively in Iraq, which places the emphasis on protective measures. And while no-one doubts their courage or professionalism, it is clear that some freedom of action has been reduced — with an obvious impact on offensive action. What, then, is the solution to this thorny problem?

Enter UCAR

Well, one way, which the US military future concepts agency Defense Advanced Research Projects Agency (DARPA) is working on with a competition between two teams (led respectively by Lockheed



Lockheed Martin's UCAR concept features a propulsive anti-torque tail system for high dash speeds.

Martin and Northrop Grumman), is to design and develop an Unmanned Combat Armed Rotorcraft (UCAR), essentially reducing the vulnerability of scout/attack helicopters by removing the crew. In such it qualifies as one of the three 'Ds' (dirty, dull and dangerous) that UAVs are best suited to take over from human pilots.

The UCAR contract was originally awarded in 2002 for Phase I, which was a 12-month initial concept development phase. In Phase II, the four orginal teams were whittled down to the present two and awarded another $10m for preliminary design. Finally, the end of this year will see one winner go on to Phase III or system demonstration and a further Phase IV for system maturation.

In November both teams received a $1·5m bridging funding to continue work in advance of a decision by DARPA, with the selection of the winner to go to Phase III by the middle of this month according to industry sources.

Concept of operations

In operation, the UCAR will be an agile stealthy (radar, infra-red, visual and acoustic) scout/attack helicopter, whose role will be to either scout ahead of Apache units, backing them up, or alternatively to provide top cover over cities and towns for US ground troops — dovetailing into their new Future Combat Systems network-centric architecture. UCARs, it is envisaged, will hunt in packs, sharing information from their sensors between each other and humans on the network. They will also need to be extremely autonomous in their operation, with a high level of AI that can respond to (probably spoken) orders like, 'check out what is behind that warehouse' and that also can navigate around, over and under obstacles in a cluttered urban environment.

Sensors, too, will have to work together to cross-cue targets and identify fleeting adversaries in a battlefield that may take place at night, with smoke, civilians, NGOs and other, less advanced, UAVs all adding to the 'fog of war'. This indeed may be the toughest part of the mission.

Lockheed Martin

Lockheed Martin's team proposal uses an F-117-style shaped design, with a single rotor, stub wings and a novel propulsive-tail, similar to the NOTAR system on MD helicopters. Unlike NOTAR, however, as well as cancelling torque from the main rotor, the propulsive tail (or PATS — Propulsive Anti Torque System) provides forward thrust which, the Lockheed Martin team says, will allow its UCAR design to reach dash speeds beyond 180kt. High speed, says LM UCAR programme director Dan Rice, is essential in the non-linear battlefield: "If they can't get to where they are going quickly — they are no use." The Lockheed-led submission is based on the internals of the Bell Model 407 helicopter, thus keeping costs down. The design will also leverage LM's well-known background in stealth to reduce the signature of the UCAR.

Also included on LM's team are Bell Helicopter Textron (air vehicle), Harris Corporation (communiactions and networks) Raytheon (sensor development) and DRS Technologies (tactical networking).

Lockheed is confident of a successful decision by DARPA later this month. "We have a very novel and innovative approach combined with an outstanding air vehicle able to do a variety of Army CONOPS and we have the best team," says Dan Rice.

Northrop Grumman

For the Northrop Grumman-led bid, its design uses the trademark Kaman twin intermeshing rotors. This, says the Northrop team, has the advantage of heavy-lifting capability with all the propulsive force being translated into lift, rather than some counteracting torque. For UCAR, the rotors have been upgraded with a new integral servo-flap which will boost the UCAR's top speed.

In October the company tested key technologies for the UCAR programme using a Japanese Yamaha RMAX unmanned helicopter to act as a surrogate UCAR. Says NG: "The RMAX trials have proven that our autonomy solution is progressing as planned."

Included on Northrop Grumman's team

Below: Manned helicopters are increasingly vulnerable over today's urban battlefields.

are Sikorsky (helicopter design, air vehicle fabrication), Kaman (intermeshing rotor), L3 Communications (networking), Rockwell Collins (avionics) and BAE Systems (mission management).

Like its competitor, the Northrop Grumman team is upbeat about its prospects in the competition, saying: "Northrop Grumman has the network centric vision, unparalleled unmanned systems experience, and the best team."

Let's now take a look at some of the key drivers behind the UCAR concept.

Autonomous

One of the most ambitious and complex parts of the UCAR concept is the high level of autonomy or AI needed to operate at the low flight levels, co-ordinate with other UCARs, respond to orders, observe rules of engagement (RoE) and conduct mission re-planning on the fly. Unlike today's Global Hawk or Predator, there will be no dedicated 'control cabin' with a joystick or mouse controller, and control may come from whichever US Army asset is networked and nearby. Says Dan Rice of Lockheed Martin: "It's 'management by exception'. The operator will only really need to get involved when things go wrong or in unforeseen contingencies. Our goal is to eliminate 'vigilant monitoring' as needed for current UAVs."

Unlike the high altitudes that Global Hawk flies at, the cluttered obstacle-strewn urban battlefield is probably the hardest one for an AI flying machine to negotiate. To address this, the UCAR will use a combination of sensors and internal terrain maps to 'find' its way about. Though it won't be intelligent enough to predict likely obstacles (although that may be incorporated in the future), the longer it spends in one area the more it will 'learn' about its surroundings and add to its terrain/geo-referenced obsctacle map. Being part of a team, the UCARs will also be able to share and swap obstacle information between themselves, improving their autonomous operations.

Hunting as a pack

The team aspect is also highly critical to make the concept work. Lockheed likens its vision of the UCAR team to a wolf pack hunting out its prey. Interaction with the UCAR 'pack' will be through a planning lead — though any member of the pack will be able to take over command in an emergency.

Key to success of the pack will be getting the manned/unmanned (MUM) interface right so that controllers (who may be sitting in the high workload environment of an Apache cockpit) will not suffer 'information overload'. Northrop has already done simulated tests that prove this concept saying: "Our manned-unmanned teaming demonstration, performed in July showed that the Air Mission Commander was easily able to control a team of six UCARs."

Voice recognition commands will enable the controller to command a UCAR team almost exactly like a human pilot, and the UCAR hunter-killer teams who also respond via voice as well, with different voices for different teams to aid situational awareness. Further in the future the system could also use 3D directional audio to alert humans to where the UCARs are or even alert them with vibrations through a tactile vest.

Affordable

Affordability, too, will be a key requirement for the UCAR. Flyaway cost is predicted to be around $4-8m per system, with substantially reduced maintenance costs compared to the Apache.

Given the low-level, high-threat environment in which the UCAR will operate, it is expected that attrition will also be a factor. With enough UCARs ordered, then economies of scale will materialise, but the complex sensors that the UCAR will need to carry means it may end up being more expensive than was originally planned. In the low-level environment, too, wear and

Right: The Northrop Grumman-led team is banking on an air vehicle using intermeshing rotors – providing high lifting power.

tear will be increased compared to other UCAV concepts. Wire strikes, dust filters, blade erosion due to sand will all have to be factored into the system as a whole.

Though the UCAR will incorporate some redundancy of systems in its airframe, it will also save weight because having no human crew to protect, it will not need to integrate crashworthy/survivable elements into the design.

Stealthy

The UCAR will also be designed to take rotary winged stealth to new levels. Although the US Army's stealthy Comanche was eventually cancelled, and vast problems remain in reducing the radar signature of something with highly visible external rotating parts, the UCAR will incorporate the latest in stealth technology, including, it has been reported, visual stealth measures. At the extremely low altitudes that the UCAR will operate, visual and acoustic stealth measures may well be more important than the traditional radar and infra-red low-observable measures — another way in which the UCAR will push the boundaries of what is possible. Both teams, as can be imagined, are extremely reluctant to go into detail on this subject apart from saying the measures will be "multispectral" and the UCAR will be "survivable in all its missions."

Sensors

A major thrust in the design is the sensor package which will have to be above and beyond what is currently fielded by Army attack helicopters. DARPA has designed a three beam laser radar (LIDAR) to provide 360° spherical situation awareness for obstacle avoidance of wires, lines or masts. Other sensors will detect the IR plume of a missile launch, alerting the UCAR to threats. Finally, a combination of sensors, such as millimetre wavelength radar and infrared will be able to detect individuals carrying weapons and classify them as hostile. A digital ESM sensor will also serve to intercept enemy comunications and radar emmissions and provide an extra level of confidence in target selection.

Sensor fusion, then, and the ability to transmit this data to humans (either on the ground, or in the air in the Apache or a mobile command post), is highly important to making the concept of UCAR viable. Making these sensors, compact, lightweight and cheap is also another important challenge for the teams.

Challenges

However, there are significant challenges in this ambitious programme. The easiest part, that of selecting a suitable platform, may be over. Making the vehicle truly stealthy may be impossible but it may not matter so much for an expendable vehicle like the UCAR.

Dealing with the ground clutter and IDing targets (which, as in Iraq, might be wearing civilian clothes and blending in with the local population) will also be a major challenge for the teams working on the UCAR. An example from 2003 suffices to show how difficult it is to make a positive ID. Footage posted on the Internet from the night vision system of an Apache which shows it engaging three figures, at night in Iraq with its 30mm chain gun, generated a storm of controversy from even professionals. Was it footage of a possible war crime of the massacre of three farmers near a tractor? Or were the Apache crew firing in self-defence against an Iraqi SAM unit which had a Strela missile nearby — but just didn't get a chance to use it? These questions, one must remember, are made with humans in the loop.

Will the UCAR be able to tell these differences? "Everything will be under operator review," says Lockheed's Dan Rice, "which will allow the operator to drill down to get the information he needs, or request a different camera angle, or even get 10 secs of video footage. The important thing is to never assume anything."

The UCAR's target verification process and RoE protocols must be a step change above what we have today, lest the US be constrained in operating its new weapon system. And there are two other factors at work here — expense and weight. To stand a better chance of IDing a target, you add more sensors to work together. However, more sensors usually add extra expense, and extra expense is what originally killed the Comanche. Since the US wants to be able to field these in packs (and given the attrition rate when they hit power lines, TV aerials, washing lines etc.) the price per unit will need to be acceptable. Extra weight will reduce air vehicle performance.

Dilution of effort?

The UCAR also has potential competition from other UAV rotorcraft such as the Fire Scout, X-50 Dragonfly, A106 Hummingbird and Boeing's optionally manned variant of the Little Bird AH-6 scout helicopter. Of course UCAR is a dedicated 'combat armed' rotorcraft optimised for nap-of-the-earth flight but, as the short history of UAVs is demonstrating rapidly, these surveillance UAV rotorcraft will probably be quickly armed, which may impinge on the UCAR role and could possibly lead to a dilution of effort in this area.

Above: Farmers or soldiers? UCAR will need to employ unprecedented levels of sensor fusion, (radar, EO/IR/LIDAR and ESM) to give more confident target data than this gun camera footage taken from a US Army Apache in Iraq.

Conclusion

The UCAR, then, promises to restore the initiative to US attack helicopters — allowing humans to stand-off the urban battlefield, directing the UCARs in to deal with manpads, RPGs and other high-threat targets.

However, after the cancellation of the highly expensive, technologically advanced Comanche, will the UCAR be able to deliver what DARPA is promising? Certainly the capability seems very ambitious — to equip an unmanned rotorcraft with an AI intelligent enough to negotiate and pathfind its way around a highly complex 3D urban battlefield, avoiding obstacles and seeking out targets. A new level of sensor fusion will detect and classify threats and prioritise them. Finally, a complex and adaptable set of RoE (able to be modified on the fly by human intervention) is required.

Though this seems more like science fiction, it has to be remembered that DARPA has an impressive track record. However, operating over the urban battlefield is possibly the hardest UAV mission to be attempted so far. If DARPA and one of its two contractors can pull this off, then UAVs will have truly come of age.

If the UCAR succeeds in its goal of high-level tasking, mission planning and re-targeting on the fly, as well as having no dedicated ground station, it could provide breakthroughs for other UAC/UCAV systems and be the direct forerunner of the "swarming" concept of UAV's that has been much discussed but has yet to be put into practice. ◆